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# Morphospecies as a substitute for Coleoptera species identification, and the value of experience in improving accuracy

**B. I. P. Barratt[1], J. G. B. Derraik[2], C. G. Rufaut[3], A. J. Goodman[4], and K. J. M. Dickinson[3]**

**Abstract** Biodiversity studies are often limited by unavailability or inaccessibility of taxonomic expertise; in New Zealand, taxonomic revisions and keys to many invertebrate groups are far from complete. To make progress with ecological and biodiversity studies, the separation of organisms into recognisable taxonomic units or morphospecies has sometimes been adopted. Coleoptera are speciose, trophically diverse, and taxonomically well known compared with other large trophically diverse groups and so they are useful to include in biodiversity studies. This study opportunistically examined the accuracy of Coleoptera species separation using morphologically recognisable features of specimens collected from three different vegetation communities, by three student researchers with different levels of training and previous expertise. Their morphospecies were examined by a single researcher with experience in taxonomy of Coleoptera. In total, 155 morphospecies were separated by the three students, compared with 151 determined by the specialist, which included representatives from 23 families of Coleoptera. All three students identified a total number of morphospecies within about 10% of the actual number, irrespective of previous training. However, the proportion of correct species separation increased from 63 to 87% in accordance with the level of previous experience. Common errors in species separation made by parataxonomists in relation to coleopteran families are discussed.

**Keywords** biodiversity; Coleoptera; morphospecies; parataxonomy; taxonomy

## INTRODUCTION

The need for biological inventory and biodiversity assessment is increasing with the realisation that species loss as a result of anthropogenic factors including habitat loss, pollution, and invasive alien species may eventually threaten the ecosystem services upon which our continued existence depends (e.g., Schulz & Mooney 1993). It is also well acknowledged that invertebrates provide the great majority of terrestrial biodiversity. Published taxonomic

[1]AgResearch, Invermay Agricultural Centre, Private Bag 50 034, Mosgiel, New Zealand. Email: barbara.barratt@agresearch.co.nz
[2]Ecology and Health Research Centre, Department of Public Health, Wellington School of Medicine Health Sciences, University of Otago, P.O. Box 734, Wellington, New Zealand.
[3]Ecology, Conservation and Biodiversity Research Group, Botany Department, University of Otago, P.O. Box 56, Dunedin, New Zealand.
[4]Wharf Road, Colville, Coramandel, New Zealand.
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description of species, especially for invertebrates and micro-organisms, are vastly incomplete (e.g., Vane Wright 1992), and the expertise available to make rapid progress in this area is inadequate. Hawksworth & Mound (1991) recognised that permanent reference collections of organisms are an essential tool for species identification and verification of names that have been used in research projects. Collections contain information on distribution, seasonality, etc., and global initiatives are needed to harness this information. One such initiative is Species 2000, which has the objective of documenting all known species on earth as the baseline dataset for studies of global biodiversity (Anon. 2000). Clearly this massive undertaking will take a very long time to reach a stage where it becomes a useful working tool for biodiversity research. Renner & Ricklefs (1994) have expressed concern about the current rush of proposals to inventory the earth's biodiversity that are carried out under the illusion that inventories of species will help to conserve biodiversity. Nevertheless, the necessary and more practically useful ecological studies with biodiversity conservation objectives clearly require agreement on the biological currency with which comparisons in space and over time can be measured.

About half of all named species are insects (May 2000), and of those about 20% are Coleoptera (Vane Wright 1992). When undescribed species and only terrestrial species are considered, the proportion is much higher. Not only are Coleoptera a large and very species-rich order, they embrace a wide range of functional groups and occur at most trophic levels. They are reported as being a good surrogate group for species richness for the entire invertebrate community (e.g., Neumann 1979; Moeed & Meads 1985), and they are acknowledged as being the group which best represents the biodiversity of vegetation systems as recognised by ecologists and land managers (Hutcheson et al. 1999). Consequently, Coleoptera are a potentially useful group to use in biodiversity studies (Hutcheson 1990). In New Zealand, it has been estimated that there are in excess of 20 000 species of insects, of which about 6000 are predicted to be Coleoptera (Emberson 1998).

Acquiring taxonomic expertise has been called the single greatest challenge for biodiversity studies (Danks 1997). In New Zealand this taxonomic impediment (Emberson 1994) and the shortage of taxonomic expertise has placed constraints on the use of invertebrate inventories for environmental monitoring and conservation evaluation in terrestrial habitats. To address this problem, it has been suggested that non-specialists or parataxonomists can be used to classify invertebrates to morphospecies, based on recognisable morphological differences between species, without compromising scientific accuracy (Oliver & Beattie 1996). Hammond (1994) limited his definition of morphospecies to recognisable taxonomic units used for taxa that have not been formally described. In New Zealand it is estimated that a little over half of the fauna has been described (Emberson 1998) and so the use of morphospecies separation represents a practical compromise to enable progress to be made in understanding the link between vegetation and associated invertebrate communities.

In a previous study in which morphospecies separation was used for Araneae, Coleoptera, and Lepidoptera, correct species separation was 91% for Lepidoptera, 63% for Coleoptera, and 50% for spiders (Derraik et al. 2002). That study suggested that accuracy of species separation could probably be enhanced by some basic taxonomic training. Oliver & Beattie (1993) pointed out that training by taxonomic specialists was vital for biodiversity technicians to carry out rapid biodiversity assessment. This study opportunistically compares the accuracy of species separation of Coleoptera by three student parataxonomists with differing levels of experience in insect taxonomy. Some assessment is therefore provided of the benefit of basic training, and of the reliability of morphospecies separation for Coleoptera when used as a tool for non-specialists to estimate species richness and biodiversity.

## METHODS

Three post-graduate students (Students 1, 2, and 3) were involved in different projects involving assessments of Coleoptera species richness. They separated morphospecies based on the external morphological characters that they were able to distinguish using ×6 to ×40 zoom binocular microscopes. In each case, a set of voucher specimens of morphospecies was examined and identified as far as possible to true species by the senior author, using a reference collection of Coleoptera from the area, and keys or revisions where available.

### Student 1

Sampling was carried out in a modified native shrubland at 450 m a.s.l. in a private covenant on the lower eastern slopes of the Rock and Pillar Range, South Island, New Zealand (45°30′S, 170°03′E). This is a region of extensive modified tussock grasslands, shrublands, and alpine vegetation. Two native divaricating shrub species *Olearia lineata* (Kirk) Cockayne (Asteraceae) and *Coprosma propinqua* A.Cunn. (Rubiaceae) were sampled by beating and pitfall trapping beneath and between shrubs. Coleoptera (and all other invertebrates) were sorted as far as possible to individual species using morphological characters, but without the use of keys or dissection of genitalia. Identification to morphospecies was carried out on dry specimens.

### Student 2

Sampling by pitfall trapping was conducted in the same protected land as that sampled by Student 1 but at 800 m in modified tall-tussock, *Chionochloa rigida* (Raoul) Zotov (Gramineae), grassland (45°30′S, 170°02′E). Traps were placed against the base of tussocks and in inter-tussock vegetation. Invertebrates, including Coleoptera, were sorted and identified as above, by examination of wet specimens in alcohol.

### Student 3

Invertebrate sampling was carried out in modified tussock grassland at 700 m a.s.l. in the Dunedin City Council Deep Stream water catchment area, about 10 km north of Lake Mahinerangi and 25 km SSE of the sample sites of the other students (45°04′S,169°51′E). This is an area of modified tussock grassland, shrubs, and predominantly native inter-tussock vegetation. Coleoptera (and other invertebrates) were sampled by taking $20 \times 0.1$ m$^2$ ($0.32 \times 0.32$ m) quadrats, 50 mm deep, from inter-tussock areas and $9 \times 0.1$ m$^2$ quadrats over tussocks. All invertebrates were extracted over a 5-day period from inverted samples placed in heat-extraction funnels. Coleoptera were sorted as far as possible to individual species using only external morphological characteristics, and most identification to morphospecies was carried out on wet specimens in alcohol.

### Analysis

The previous experience of the students was assessed using a questionnaire. Answers were standardised as far as possible and a relative measure of experience was determined (Table 1). No further training was given to the students before they commenced their respective studies.

Accuracy of the students, as assessed by the senior author, was calculated at the species level. Correct species separation was only recorded when a single species was consistently separated from other taxa. This gave a conservative assessment of accuracy, since in some instances taxa were correctly separated from others, but if two or more taxa were confused within that new taxon, then this was classified not as incorrect, but as lumped. Thus, species 1 always identified as only morphospecies A = correct; species 2 and 3 identified as morphospecies B = lumping; species 4 identified as morphospecies C and D = splitting.

## RESULTS AND DISCUSSION

The relative level of experience of the three students before undertaking their specific studies is shown in Table 1. Student 1 was trained in ecology and botany, with no invertebrate content in undergraduate or post-graduate courses, or in any research positions held. Student 2 was trained in zoology, ecology, and wildlife management, with some invertebrate taxonomy included; research assistant positions gave basic training in sorting and identification of larger invertebrates. Student 3 was trained in zoology, ecology, and wildlife management, with invertebrate taxonomy included; several research assistant positions involved basic training in invertebrate sorting including identification of insects to orders and families.

In total, 155 morphospecies were separated by the three students, compared with 151 determined by the senior author. The species ranged over 23 families of Coleoptera (Table 2), 10 of which were common to all three studies. Carabidae, Coccinellidae, Curculionidae, and Staphylinidae were the four families best represented in the collected material. The number of species involved in the three studies was similar for Students 1 and 3 (58 and 61), but Student 2 collected about half this number (32) (Table 2). Several species were common to either two or all three of the collections.

All three students identified a total number of morphospecies within about 10% of the actual species number determined by the senior author, irrespective of previous training (Table 2). This, however, embraced a degree of "fortuitous congruence" (Oliver & Beattie 1993) with splitting and lumping errors cancelling each other out. The proportion of correct species separation increased from 63 to 87% in accordance with the level of previous

**Table 1** Questionnaire used to determine comparative levels of proficiency of students. ✓, low level of proficiency; ✓✓, moderate level of proficiency; ✓✓✓, high level of proficiency.

| | Student | | |
|---|---|---|---|
| Questions | 1 | 2 | 3 |
| Academic qualification | BSc Ecology | MSc Zoology | BSc Zoology |
| Did courses include invertebrate taxonomy? | | ✓ | ✓ |
| Did courses include taxonomy of Coleoptera? | | | ✓ |
| Relevant practical post-graduate experience including insect identification | | ✓ | ✓✓ |
| Were you given training in identification of Coleoptera? | | ✓ | ✓ |
| Before beginning morphospecies separation, could you separate Coleoptera from other orders? | ✓ | ✓✓ | ✓✓ |
| Could you recognise different families of Coleoptera? | | ✓ | ✓✓ |
| Have you ever used a key to identification of invertebrates? | | ✓ | ✓ |
| Have you ever used a key to identification of Coleoptera? | | | |
| In separating morphospecies, were books with descriptions or illustrations of Coleoptera used? | | ✓ | |
| Did you have any other assistance in separating Coleoptera morphospecies? | | | |
| Total ✓ | 1 | 8 | 10 |

experience (Table 1; Fig. 1). The two more experienced students (Students 2 and 3) lumped species less frequently than Student 1. Species splitting showed no clear relationship with experience (Fig. 1), but four instances of splitting by Student 1 involved a genus of small variable curculionid species, which was not represented in the collections of the other students.

At the insect order level, two students wrongly identified small lygaeids (Hemiptera: Heteroptera) as Coleoptera. This was the only error made at that level.

Identification of Coleoptera, as for many other invertebrate groups, depends to some extent on examination of surface texture, pubescence, colour, etc. These features are usually more visible on air-dried specimens than on those submerged in fluid. Student 3 found that it was necessary to air-dry weevil species of the genus *Baeosomus* (Coleoptera: Erirhinidae) to

**Table 2** Total number of morphospecies and species involved in each study, and accuracy of species separation by students shown for families of Coleoptera encountered. Species separation is shown as C, correct; S, split; L, lumped as assessed by the senior author. Where a family was not represented in the collection by a particular student, this is shown as a dash. A zero denotes no incidence of correct, split, or lumped species determinations.

| | Student | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 2 | | | 3 | | |
| Total Coleoptera morphospecies | 54 | | | 33 | | | 68 | | |
| Total Coleoptera species | 58 | | | 32 | | | 61 | | |
| | Number of morphospecies separations | | | | | | | | |
| Coleoptera families | C | S | L | C | S | L | C | S | L |
| Anthribidae | 2 | 0 | 0 | – | – | – | – | – | – |
| Byrrhidae | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 |
| Carabidae | 0 | 2 | 2 | 6 | 1 | 0 | 8 | 0 | 1 |
| Cerambycidae | 2 | 0 | 0 | – | – | – | 1 | 0 | 0 |
| Chrysomelidae | – | – | – | 1 | 0 | 0 | 1 | 0 | 0 |
| Coccinellidae | 5 | 2 | 2 | 4 | 0 | 0 | 4 | 1 | 0 |
| Colydiidae | 1 | 0 | 0 | – | – | – | – | – | – |
| Corylophidae | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Cryptophagidae | 2 | 0 | 0 | – | – | – | 1 | 0 | 0 |
| Curculionidae | 7 | 0 | 2 | 1 | 0 | 0 | 15 | 4 | 0 |
| Dermestidae | – | – | – | 1 | 0 | 0 | 1 | 0 | 0 |
| Elateridae | – | – | – | 1 | 0 | 0 | 1 | 0 | 0 |
| Latridiidae | 1 | 1 | 1 | 4 | 1 | 0 | 1 | 0 | 0 |
| Leiodidae | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 |
| Melyridae | – | – | – | – | – | – | 1 | 0 | 0 |
| Pselaphidae | – | – | – | – | – | – | 4 | 0 | 0 |
| Ptilidae | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Scarabaeidae | 0 | 1 | 0 | 2 | 0 | 0 | 2 | 0 | 0 |
| Scirtidae | 1 | 0 | 0 | – | – | – | 1 | 0 | 0 |
| Scydmaenidae | – | – | – | – | – | – | 1 | 1 | 0 |
| Staphylinidae | 5 | 2 | 3 | 5 | 1 | 1 | 11 | 0 | 0 |
| Tenebrionidae | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 2 | 0 |
| Trogossitidae | 1 | 0 | 0 | – | – | – | – | – | – |
| Total | 32 | 9 | 10 | 27 | 3 | 2 | 61 | 8 | 1 |

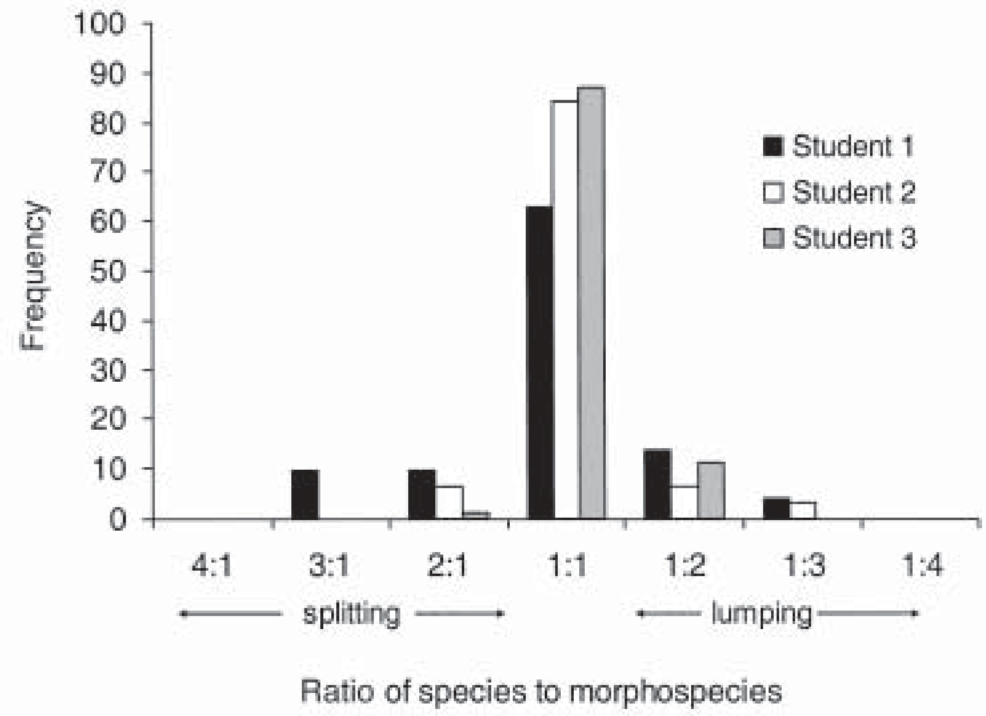


**Fig. 1** Frequency of species separation by three student parataxonomists.

facilitate morphospecies separation, but otherwise specimens were examined in ethanol. Only Student 1 examined all specimens dry, which may have conferred a relative advantage in species separation, but Student 1 was the least experienced parataxonomist (Table 1) and still recorded the lowest accuracy.

An examination of morphospecies separation in relation to the families of Coleoptera represented in the study shows that all three parataxonomists made species separation errors in Carabidae. Lumping errors occurred mainly as a result of grouping by size, when in fact there were often more than one species in each size class. Two parataxonomists made errors with Coccinellidae, Latridiidae, and Staphylinidae, which were generally small native species and differences between species were often quite subtle (e.g., Aleocharinae). Errors were also common with Curculionidae, arising from splitting genders of the same species where sexual dimorphism was pronounced. Also, confusion arose between small, morphologically very similar species of weevils, where genitalia dissection is required by taxonomists for accurate identification, e.g., Entiminae: Tropiphorini, and Erirhininae: Stenopelmini. While these groups still require taxonomic revision, morphospecies decisions were applied consistently by the senior author using internal genitalia characteristics.

Although the three students were working with different coleopteran assemblages collected by different techniques, the study has provided evidence to suggest that non-specialist taxonomists separate species of Coleoptera with a varying degree of accuracy, related to the level of previous training and experience. A more accurate assessment of the benefits of training would be to take a number of students who had completed the same background training, provide half of them with some basic invertebrate taxonomic training, and then compare their levels of accuracy in morphospecies separation using the same insect material.

Account should also be taken of the likely variability between students, even with the same training.

Beattie & Oliver (1994) coined the phrase "taxonomic minimalism" which includes the use of higher taxonomic ranking (e.g., sorting to genus or higher level of classification for monitoring environmental change, etc.) and parataxonomy which is basic training to prepare and sort specimens to morphospecies for eventual full taxonomic identification. The latter is usually employed for local or regional collections as distinct from global collections. These authors pointed out that morphospecies can be used as surrogates for species in data analyses if the level of separation achieved by a parataxonomist is close to that of the true number of species. The highest level of accuracy achieved in this study by the most experienced morpho-taxonomist was 87% correct species separation. Clearly this alone is unlikely to be accurate enough for biodiversity research carried out for conservation purposes or impact assessment studies where reliable baseline data are required, or for species richness analyses. However, specialist examination of morphospecies voucher specimens, and correction of relatively few splitting and lumping errors, could be performed quite rapidly compared with full taxonomic identification. This, in parallel with further training in relation to errors made, could result in morphospecies separation accuracy of almost 100%.

Clearly, skilled taxonomic input is essential for species inventory or comparative biodiversity studies, but preliminary morphospecies separation could be very beneficial in reducing the specialist's time for sorting and specimen preparation. Interactive teams of parataxonomists and specialists would require an initial high level of taxonomic input, which would decline as the skills of the parataxonomists increase and good reference collections are established.

In future, the taxonomic impediment to biodiversity studies may benefit from new technology such as image analysis which can provide pattern recognition and the potential for automation of species separation and even identification (Weeks & Gaston 1997; Weeks et al. 1999). Even web-based digital photographic imaging of species encountered during biodiversity or ecological studies would provide a resource that could assist researchers in the same team, or those working in similar habitats in the future. Given the increasing requirement and urgency for biodiversity information, and the shortage of skilled taxonomic expertise, it is important that available methods be used to meet these needs, as long as the constraints are understood.

## CONCLUSIONS

While the need for biodiversity assessment for conservation, community ecology studies, and environmental impact assessment continues to increase, the amount of taxonomic training received by undergraduates in biological studies is diminishing and the number of professional systematists is declining as they retire and are not replaced (Penman 2002). This dilemma is receiving attention globally by the adoption of the Global Taxonomy Initiative by the Convention of Biological Diversity (Anon. 2001), but, in the mean time, alternative approaches to providing biodiversity information are required. Fortunately, students wishing to pursue research in this area have shown resourcefulness in seeking out methods such as morphospecies determination as a prelude to obtaining assistance from taxonomists for verification. The results of this study indicate that this partnership can work well and can facilitate the delivery of valuable biodiversity information.

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